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STABILITY OF FREQUENCY-WAVENUMBER NOISE SPECTRA AT UBO

8 September 1967

Prepared For

AIR FORCE TECHNICAL APPLICATIONS CENTER
Washington, D. C.

By

R. L. Sax
TELEDYNE, INC.

Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY
Nuclear Test Detection Office
ARPA Order No. 624

STABILITY OF FREQUENCY-WAVENUMBER NOISE SPECTRA AT UBO

SEISMIC DATA LABORATORY REPORT NO. 197

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ABSTRACT

Seven four-minute samples of the ambient noise were subjected to frequency-wavenumber (F-K) spectral analysis in order to observe the range and character of variations in the F-K power spectrum. The observations are derived from the same normal population. The apparent variation in the underlying noise statistics or processes do not suggest gradual diurnal variations in the noise power, but large and apparently random inter-day fluctuations.

PROCEDURE

The SDL wavenumber-frequency analysis program VFKSPTRM due to McCowan and Jih was used to analyze seven four-minute samples of ambient noise recorded at the UBO vertical array on 14 April 1967, starting at 3/20/00.00, 4/42/00.0, 6/20/00.0, 9/00/00.0, 11/20/00.0, 14/00/00.0, and 15/15/00.0. Spectral peaks were observed at nearly infinite vertical velocity at 0.20 cps, 0.80 cps, 1.50 cps, and 2.00 cps. The variability of power observed at these frequency was subjected to Bartlett's test for homogeneity of variance (Kullback, 1959). For better accuracy the high frequency peaks were observed after bandpass filtering in order to prevent leakage through the spectral window due to the large .20 cps peak.

TIME VARIATION OF THE SPECTRAL PEAK

Table 1 lists relative values of the spectral power observed at different times during the day at the specified frequency of F-K peaks observed in the noise. The vertical wave number of the peaks is nearly zero in all cases.

The .2 cps noise power was taken from the F-K spectral plots on Figures 1 to 7 with all observations normalized to the mean at .2 cps. The strip at the bottom of the Figures show the array response. The other observations were taken from the power spectral plots of band passed (.3 to 3 cps) data on Figures 8 to 14.

MEAN, RANGE, AND STABILITY OF PEAK POWER AT EACH FREQUENCY

The arithmetic mean value observed for the spectral peaks in the noise is taken from Table 1, as is the range between the lowest and highest observation in the time interval between 3/20/00.0 and 15/19/00.0. The parameter t is measured for testing the hypothesis that the observed variability of variances is due to sampling and that the underlying

variance of the noise field is time invariant

$$T = 2(BT)(B'X) \sum_{i=1}^{7} \log S^2/S_i^2 \quad S^2 = \frac{1}{7} \sum_{i=1}^{7} S_i^2$$

where B is bandwidth of frequency analysis

T is time-length of sample

X is length of the vertical array

B' is bandwidth of wave number analysis.

There is no spatial smoothing in the program, so $B'X \approx 1$. This can be verified from the array response (using 3 km. for the length of the array). The smoothing of power in time results in $B \approx .05$ cps and the time-length of the sample is 204 sec. The results of the t test are shown on Table 2. For acceptance of the hypothesis of homogeneity of variance t should be less than 12.63 in Fisher's B^2 distribution.

RESULTS

The probability of error in rejecting the hypothesis that the .2 cps noise is stationary is considerably greater than 0.05, and therefore we should not reject, but the power for acceptance of stationarity is probably low for this test. The result for the 0.8 cps peak is also marginal. We reject stationary recognizing that the probability of error is close to 0.05 if the statistics and processes underlying the .8 cps peak are indeed stationary. In the case of the high-frequency peak at 1.5 cps and 2.0 cps respectively we can decisively reject the hypothesis that the random variates underlying the observed sample variances are from the same noraml population. The high-frequency noise above 1 cps appears to be very non-stationary when viewed over a 12 hour time span. There is no obvious diurnal trend in the observed spectral power of the high-frequency

peaks.

The character of the noise as seen on Figures 1 through 4 shows a high degree of symmetry, indicating that energy conversions resulting in more up-going or down-going energy are not "observed" to play an important role in the ambient noise. There is no obvious indication of reflected P-pulses although such noise may be obscured by the array response.

REFERENCES

Kullback, S., Information Theory and Statistics, Wiley, 1959, p. 319.

TABLE 1

Time / Frequency	3/20/ 00.0Z	4/42/ 00.0Z	6/20/ 00.0Z	9/00/ 00.0Z	11/20/ 00.0Z	14/00/ 00.0Z	15/15/ 00.0Z	Mean
.2 cps	1.35	1.02	1.14	0.79	1.05	0.64	1.02	1.00
.8 cps	0.04	0.10	0.06	0.03	0.05	0.03	0.06	0.06
1.5 cps	0.006	0.010	0.037	0.001	0.007	0.002	0.035	0.014
2.0 cps	0.011	0.003	0.002	0.005	0.010	0.034	0.002	0.017

TABLE 2

Frequency	Mean Power	Range of Power	t	Hypothesis of Homogeneity
.2 cps	1.00	0.64-1.35	9.7	Accepted
.8 cps	0.06	0.03-0.10	12.9	?
1.5 cps	0.014	0.001-0.037	91	Rejected
2.0 cps	0.017	0.002-0.055	98	Rejected

VFKSPTRM AMBIENT NOISE, UBO, STARTING AT 3/20/0 Z

SEQUENCE NO. = 110/0 NO. OF CHANNEL = 8

SAMPLING RATE = 80.00 STARTING POINT = 1 TOTAL POINTS = 4096

THE NUMBER OF SMOOTHING TIME = 5

CHANNEL ID	SCALE FACTOR	DEPTH	U M	SYMBOL
CH1	1.00	0.710	0 - 5	0
CH2	1.00	0.110	6 - 9	6
CH3	1.00	0.110	10 - 15	0
CH4	1.00	1.000	16 - 21	0
CH5	1.00	1.490	04 - 07	*
CH6	1.00	1.13		

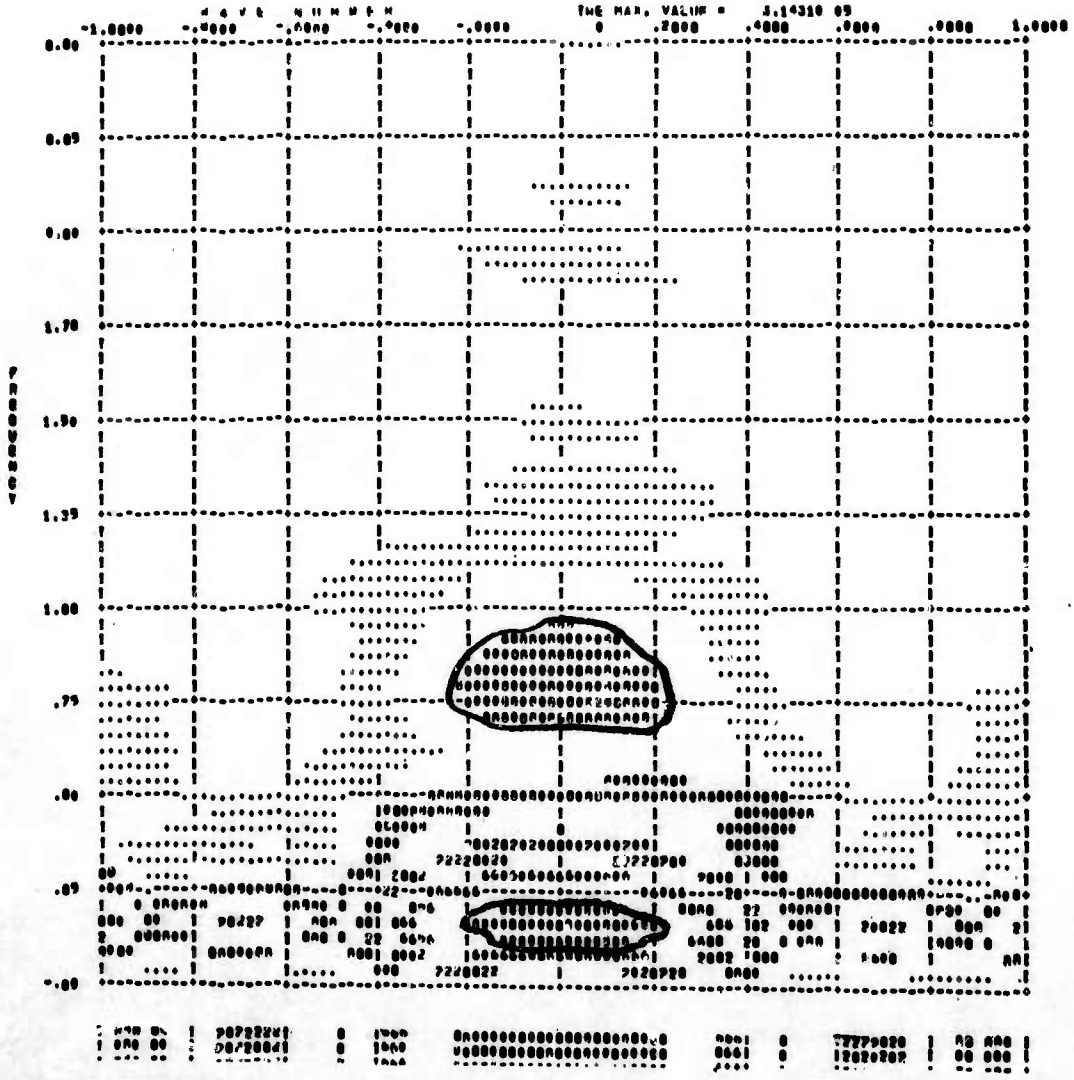

Figure 1. Unfiltered Noise

VFKSPTRM AMBIENT NOISE, URO, STARTING AT 4/42/00.0 Z

SEISMOGRAM NO. = 11698 NO. OF CHANNEL = 9

SAMPLING RATE = 20.00 STARTING POINT = 1 TOTAL POINTS = 4000

THE NUMBER OF SMOOTHING TIME = 5

CHANNEL ID	SCALE FACTOR	DEPTH	D O	SYMBOL
DH1	1.00	2.710	0 - 3	0
DH3	1.00	2.110	6 - 9	6
DH4	1.00	1.800	12 - 15	0
DH5	1.00	1.490	18 - 21	0
DH6	1.00	1.130	24 - 27	.

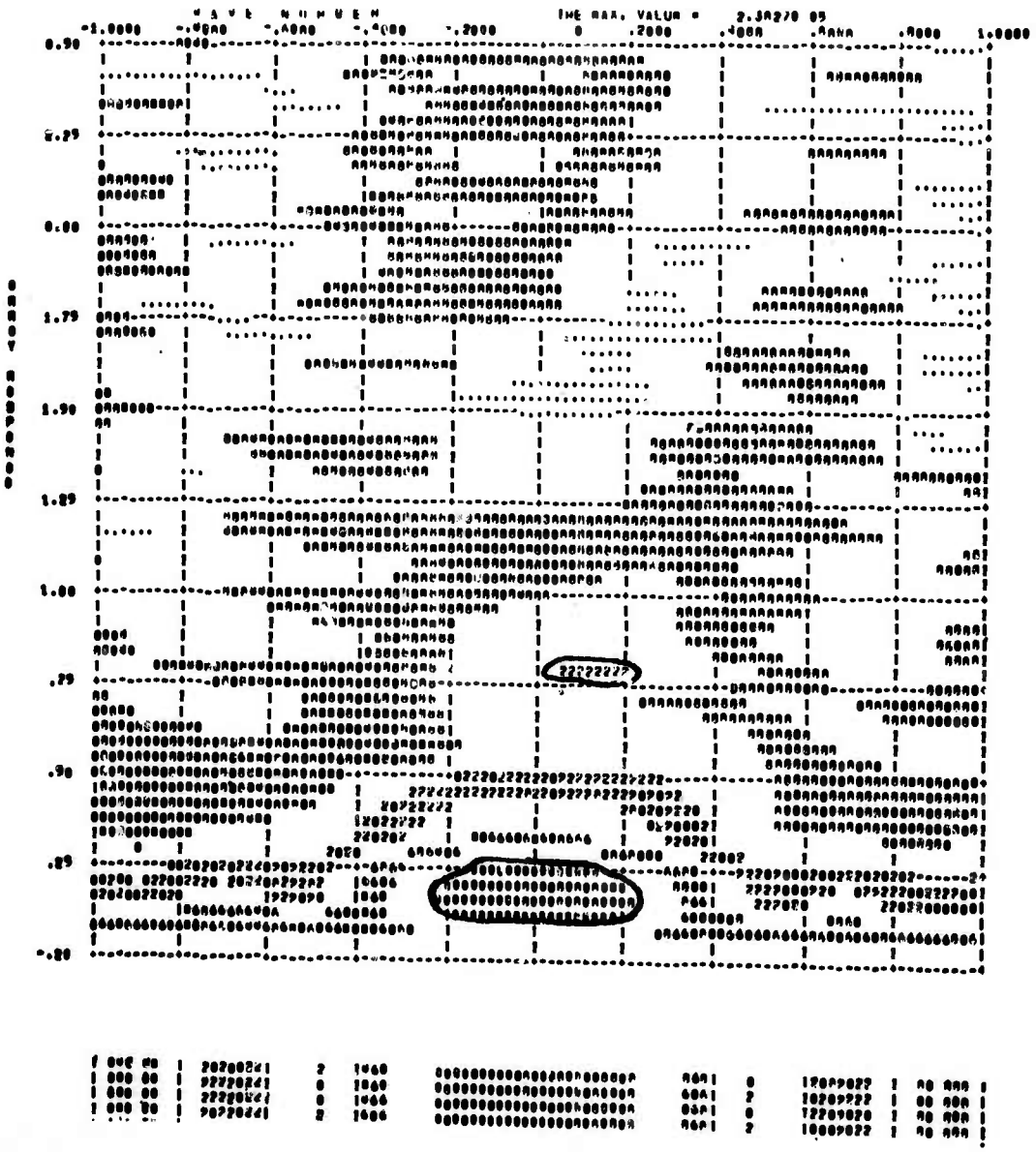

Figure 2. Unfiltered Noise

VFKSPTRM AMBIENT NOISE, UNO, STARTING AT 6/20/0.0 Z

SEISMOGRAM NO. = 11691 NO. OF CHANNEL = 9

SAMPLING RATE = 20.00 STARTING POINT = 1 TOTAL POINTS = 4096

TWO NUMBER OF SMOOTHING TIME = 5

CHANNEL ID	SCALE FACTOR	DEPTH
DW1	1.00	2.710
DW3	1.00	2.110
DW4	1.00	1.800
DW5	1.00	1.490
DW8	1.00	1.130

D M	SYMBOL
0 - 5	0
6 - 9	8
12 - 15	2
16 - 21	8
24 - 27	.

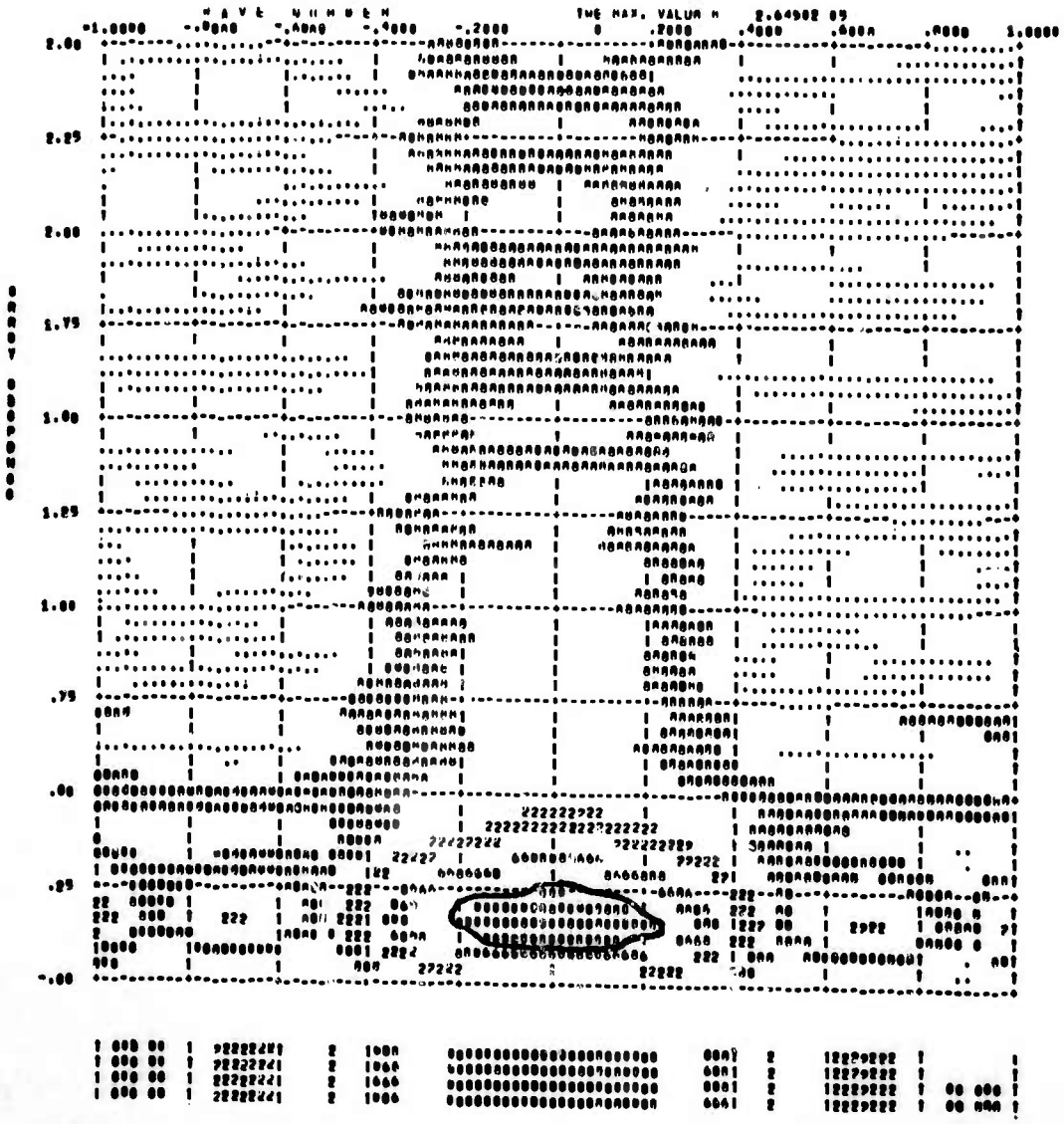

Figure 3. Unfiltered Noise

VFKSPTRM AMBIENT NOISE. UBO. STARTING AT [illegible]/00/00.0 Z

DIAGRAM NO. = 11892 NO. OF CHANNEL = 5

SAMPLING RATE = 20.00 STARTING POINT = 1 TOTAL POINTS = 4096

THE NUMBER OF SMOOTHING PTS = 5

CHANNEL ID	SCALE FACTOR	DEPTH	U R	SYMBOL
Dm1	1.00	2.710	0 - 3	0
Dm3	1.00	2.110	6 - 9	0
Dm4	1.00	1.800	12 - 15	2
Dm5	1.00	1.490	18 - 21	0
Dm6	1.00	1.130	24 - 27	.

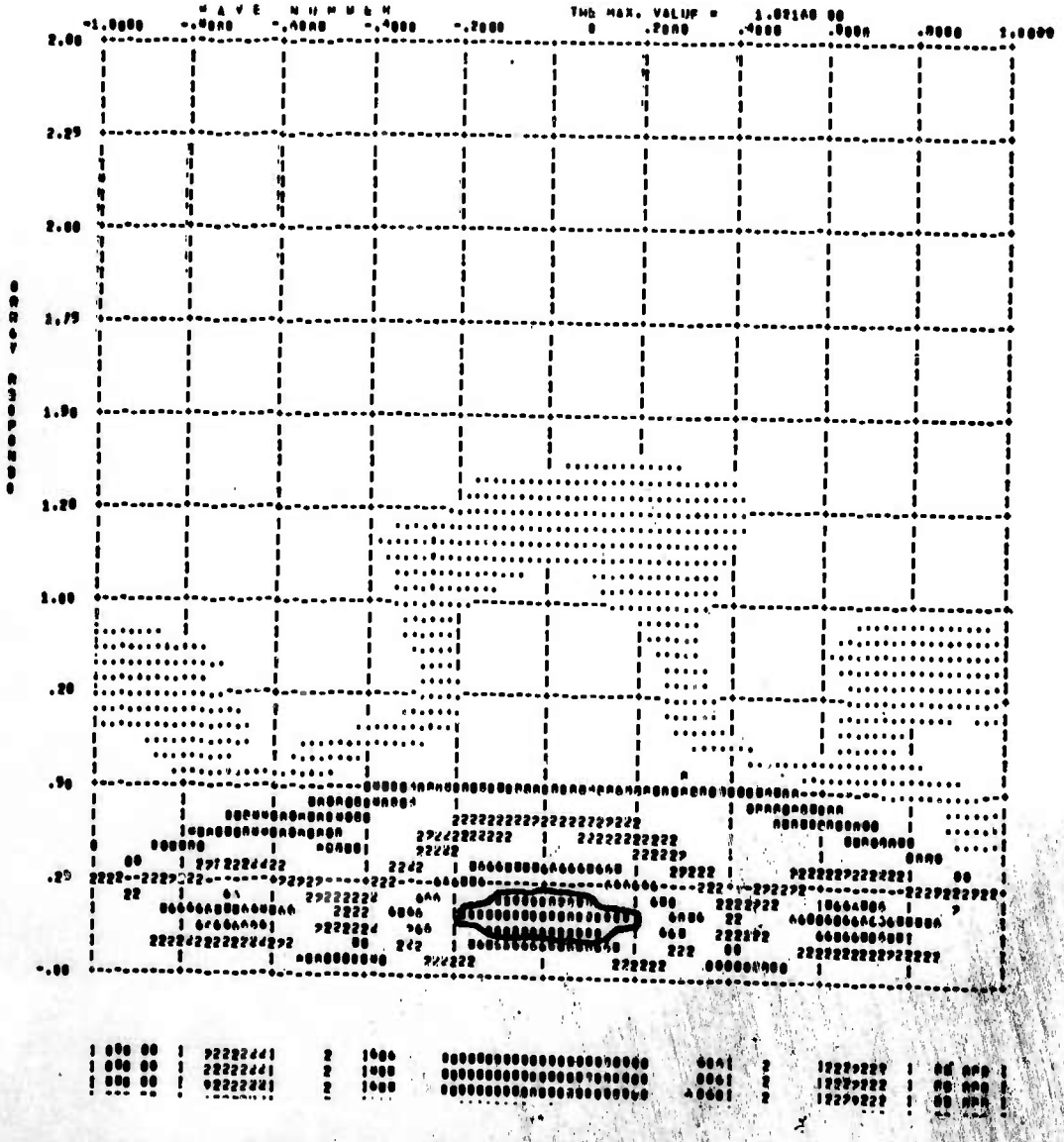

Figure 4. Unfiltered Noise

VFKSPTRM AMBIENT NOISE. UBO. STARTING AT 11/20/00.0 Z

OBSERVATION NO. = 11003 NO. OF CHANNEL = 5

SAMPLING RATE = 20.00 STARTING POINT = 1 TOTAL POINTS = 4096

THE NUMBER OF SMOOTHING TIME = 5

CHANNEL ID	SCALE FACTOR	DEPTH	U A	SYMBOL
OW1	1.00	2.710	0 - 3	0
OW3	1.00	2.110	8 - 9	3
OW4	1.00	1.690	12 - 15	2
OW5	1.00	1.490	18 - 21	0
OWR	1.00	1.130	24 - 27	

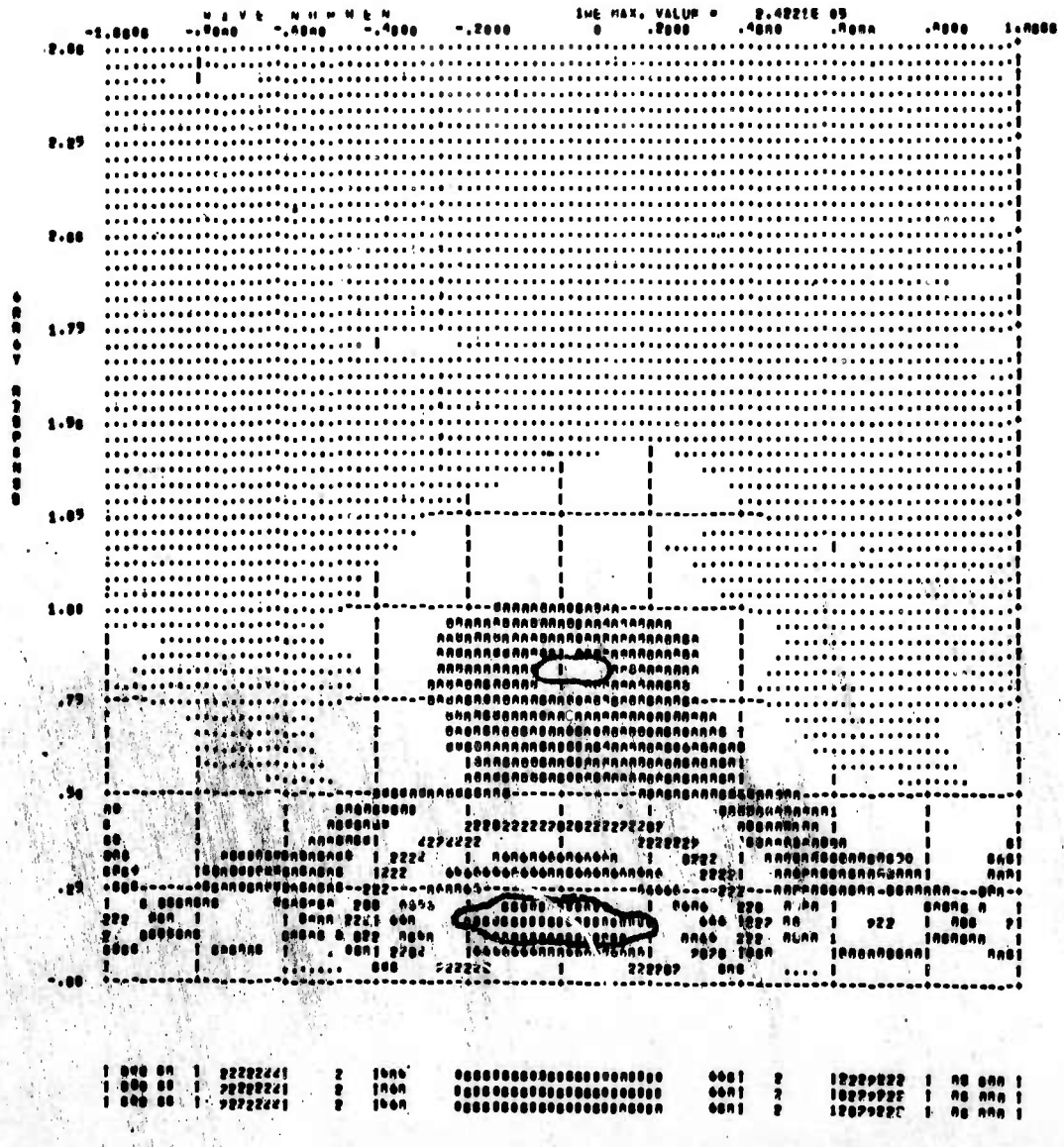

Figure 5. Unfiltered Noise

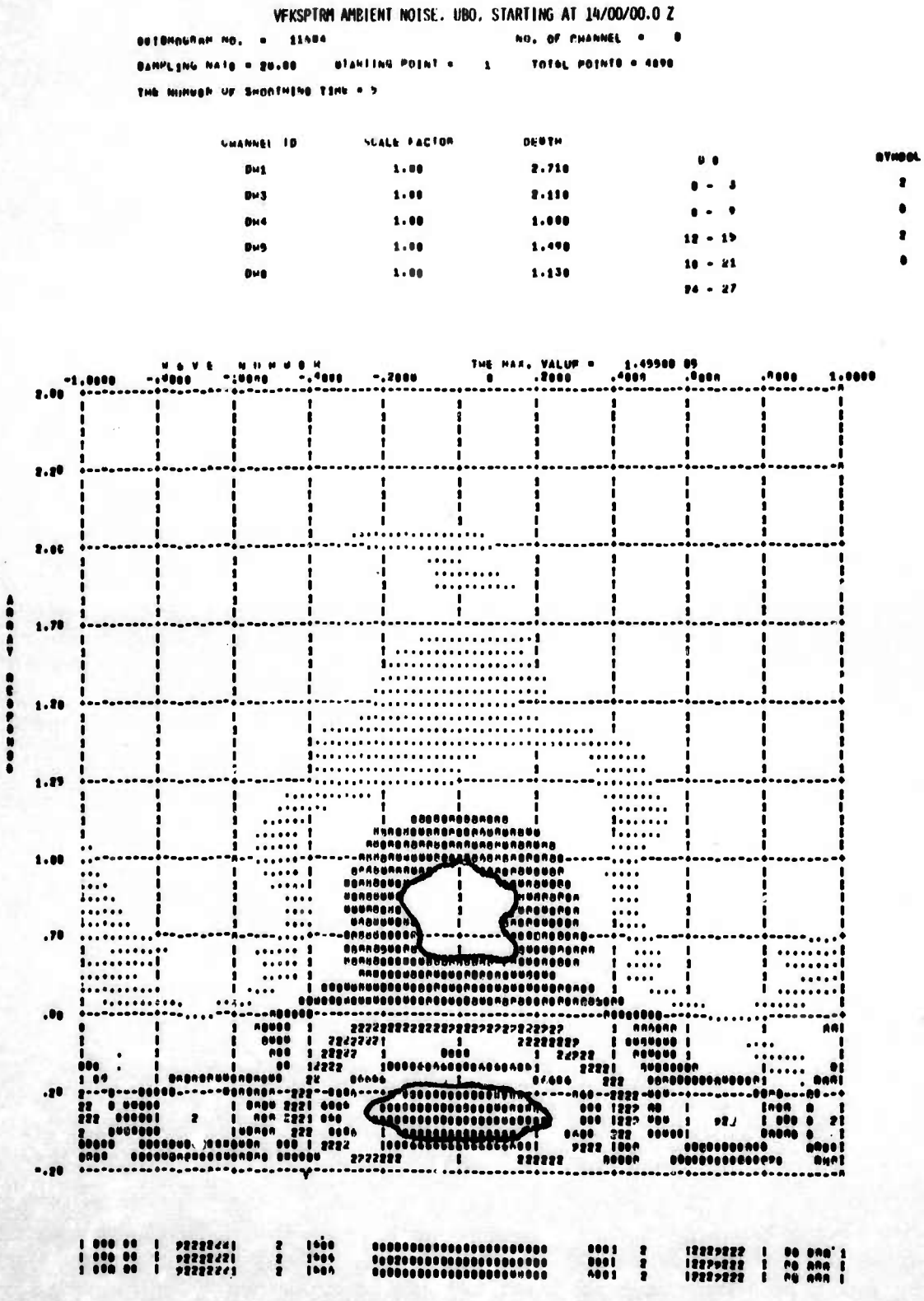

Figure 6. Unfiltered Noise

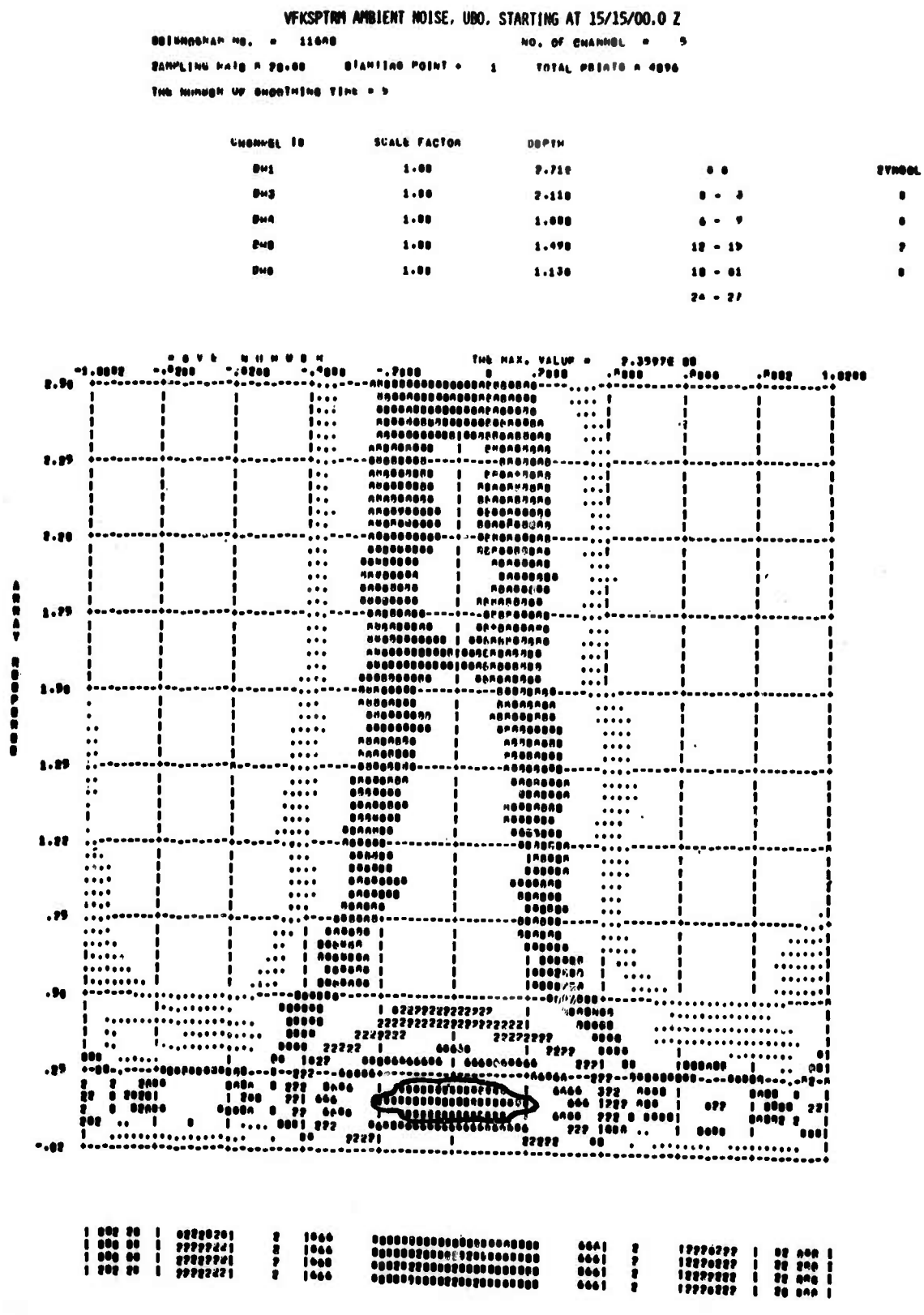

Figure 7. Unfiltered Noise

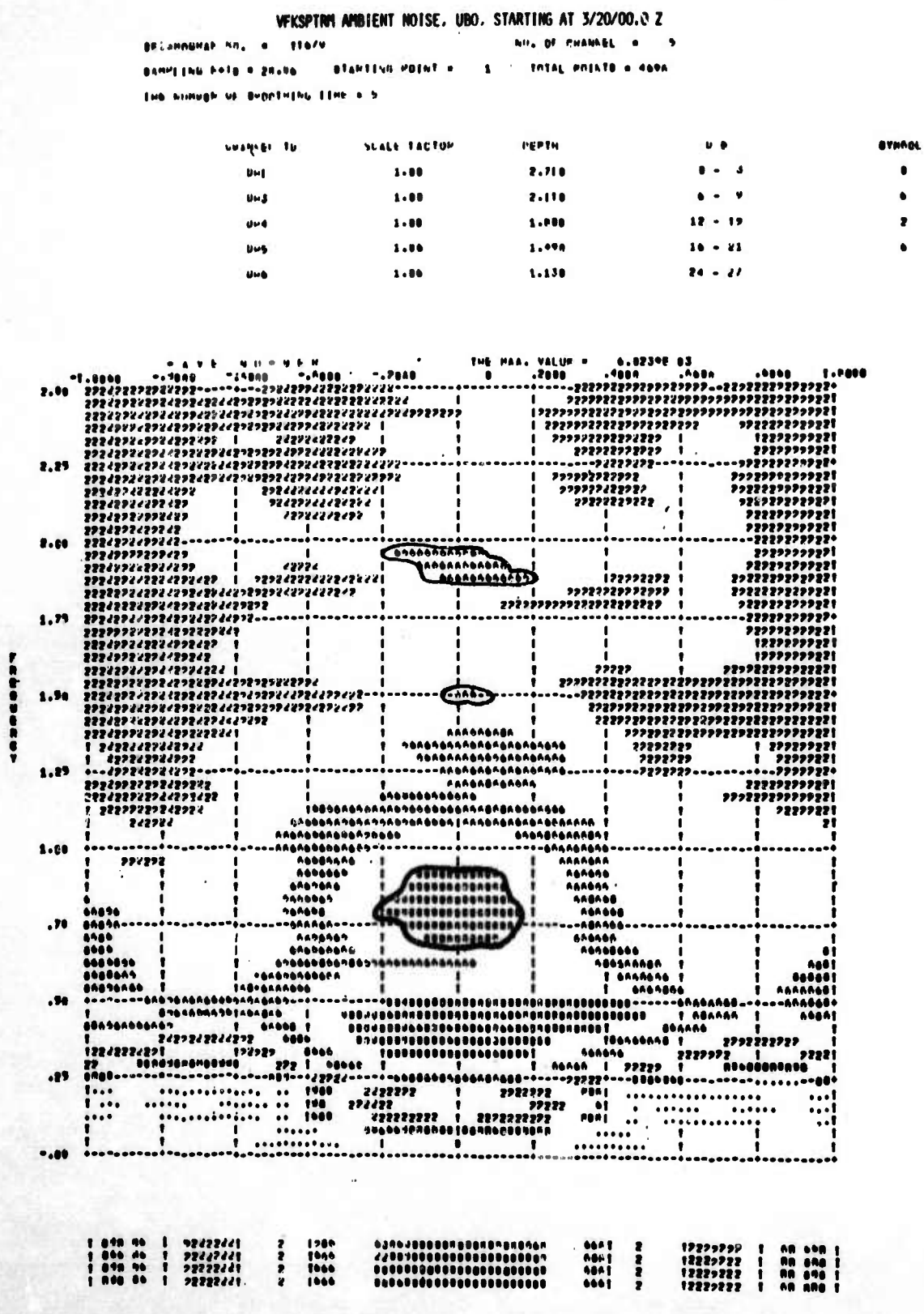

Figure 8. Filtered Noise Band:(.3<f<3cps)
Rolloff: .1cps

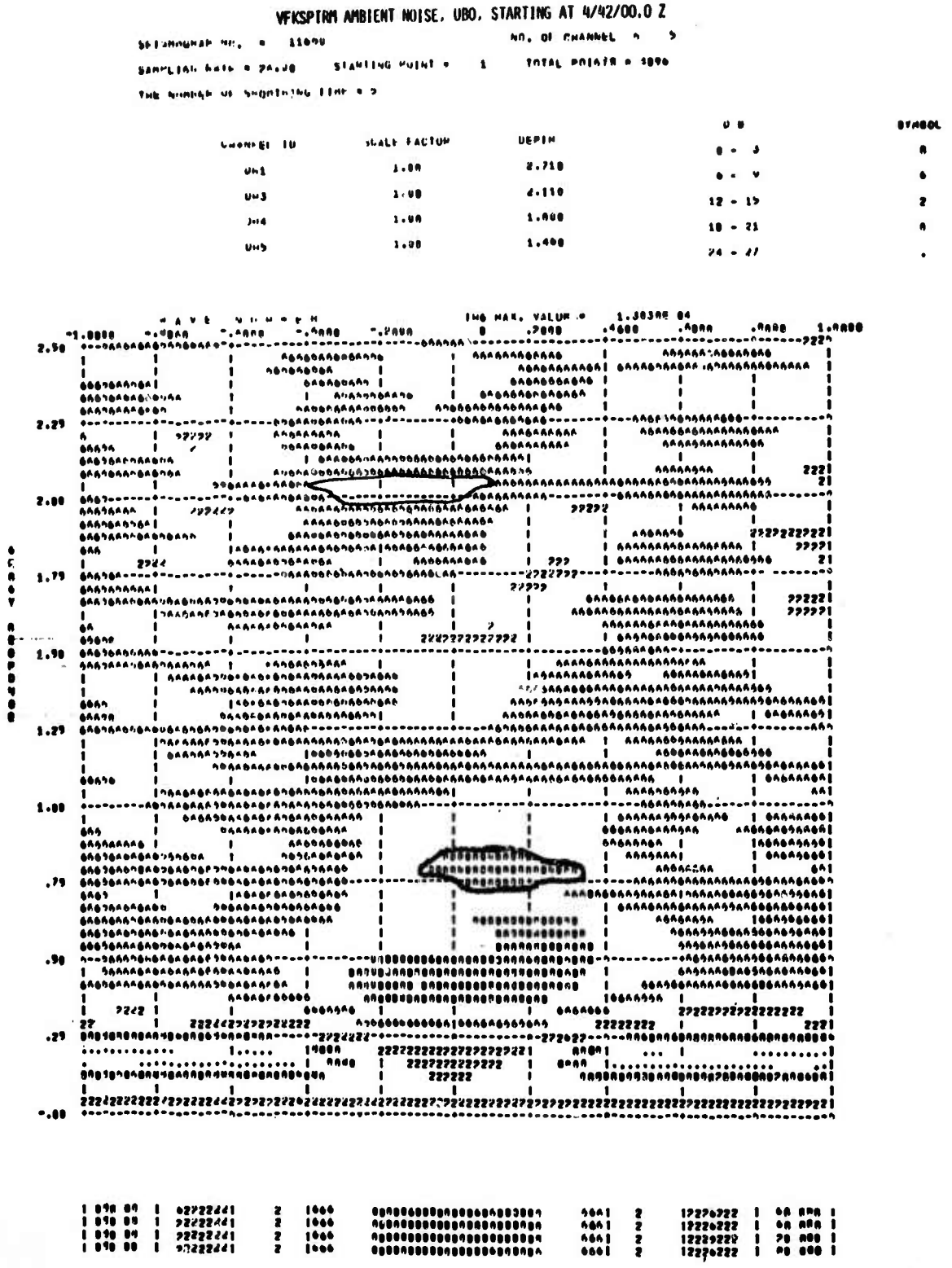

Figure 9. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

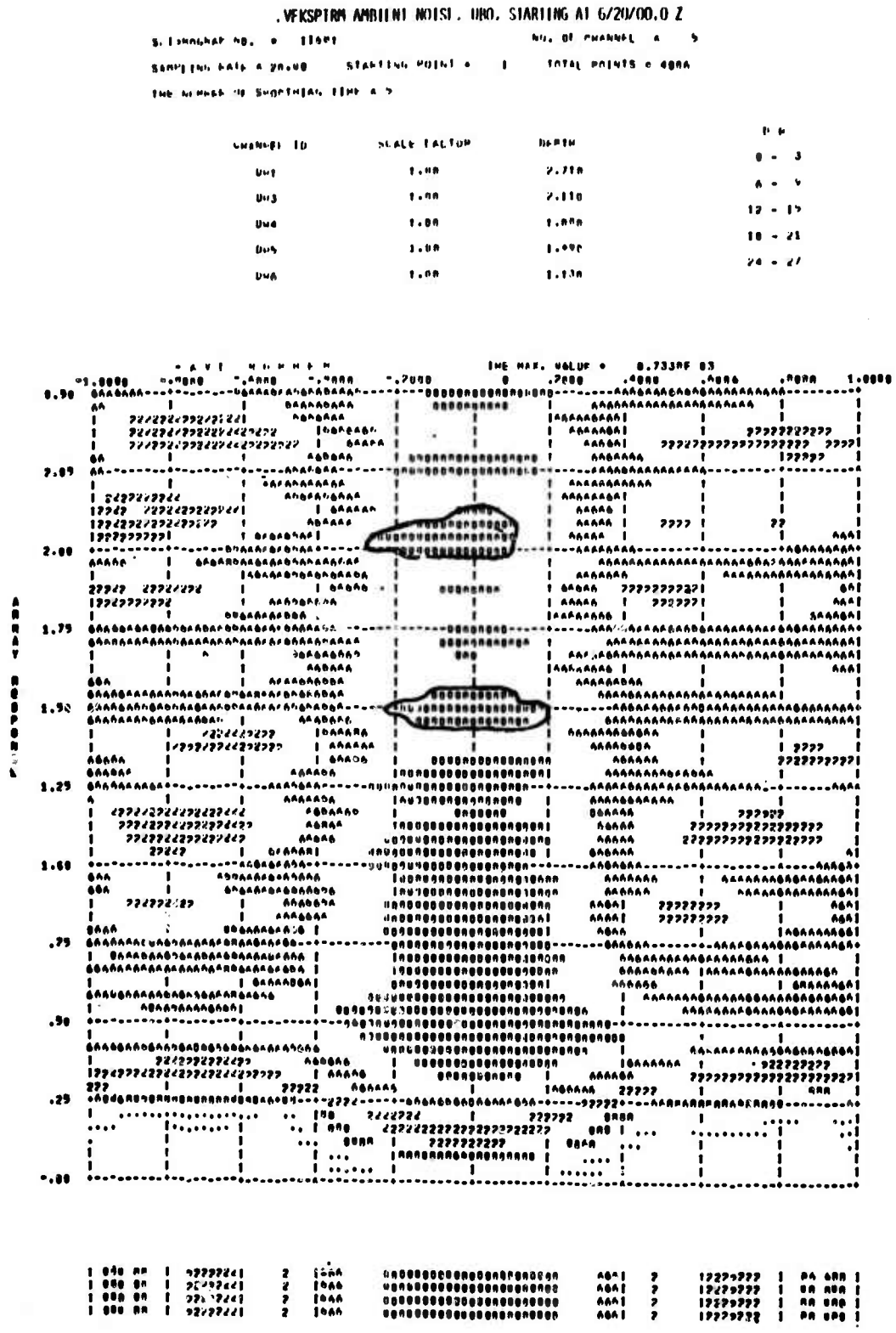

Figure 10. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

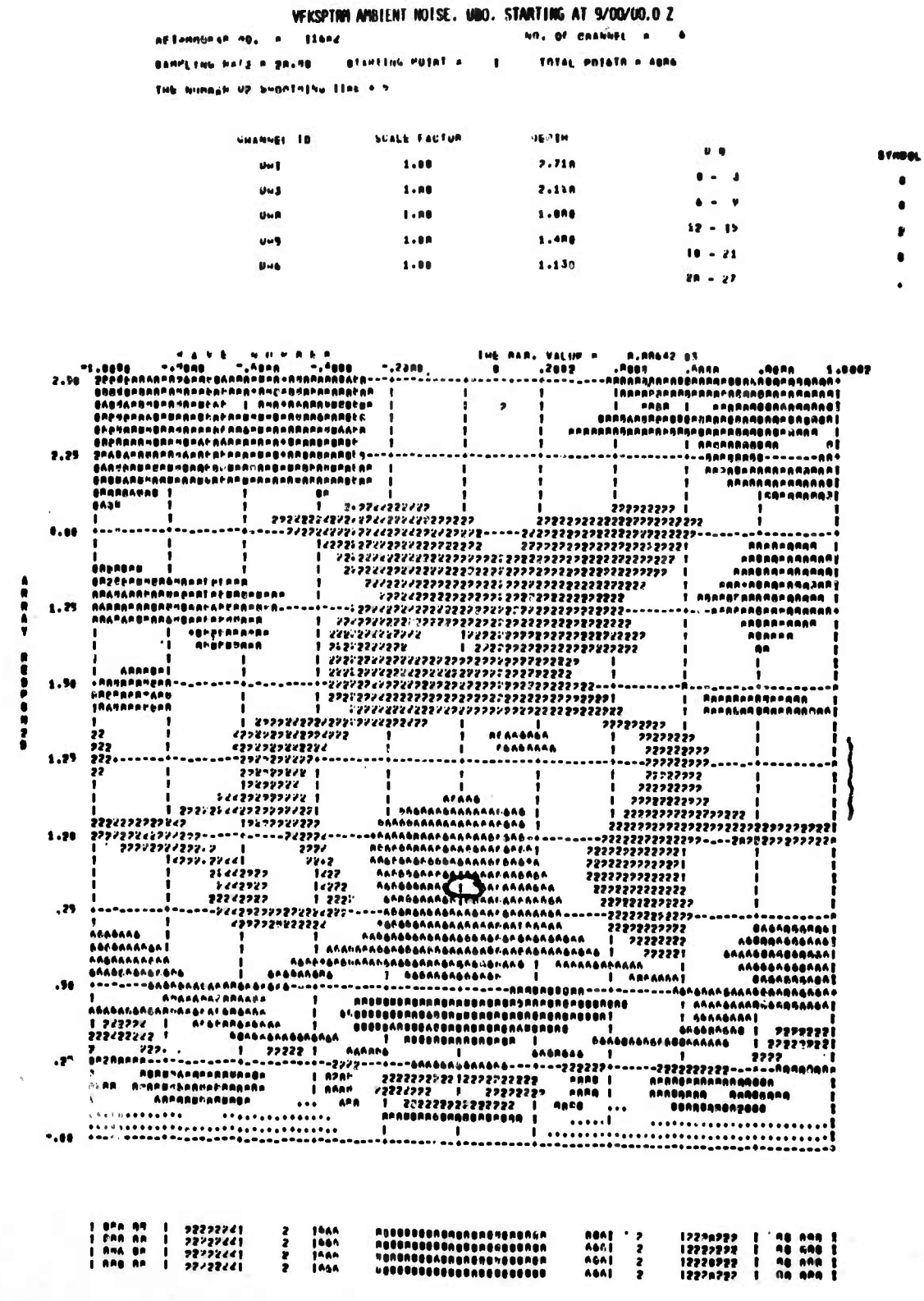

Figure 11. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

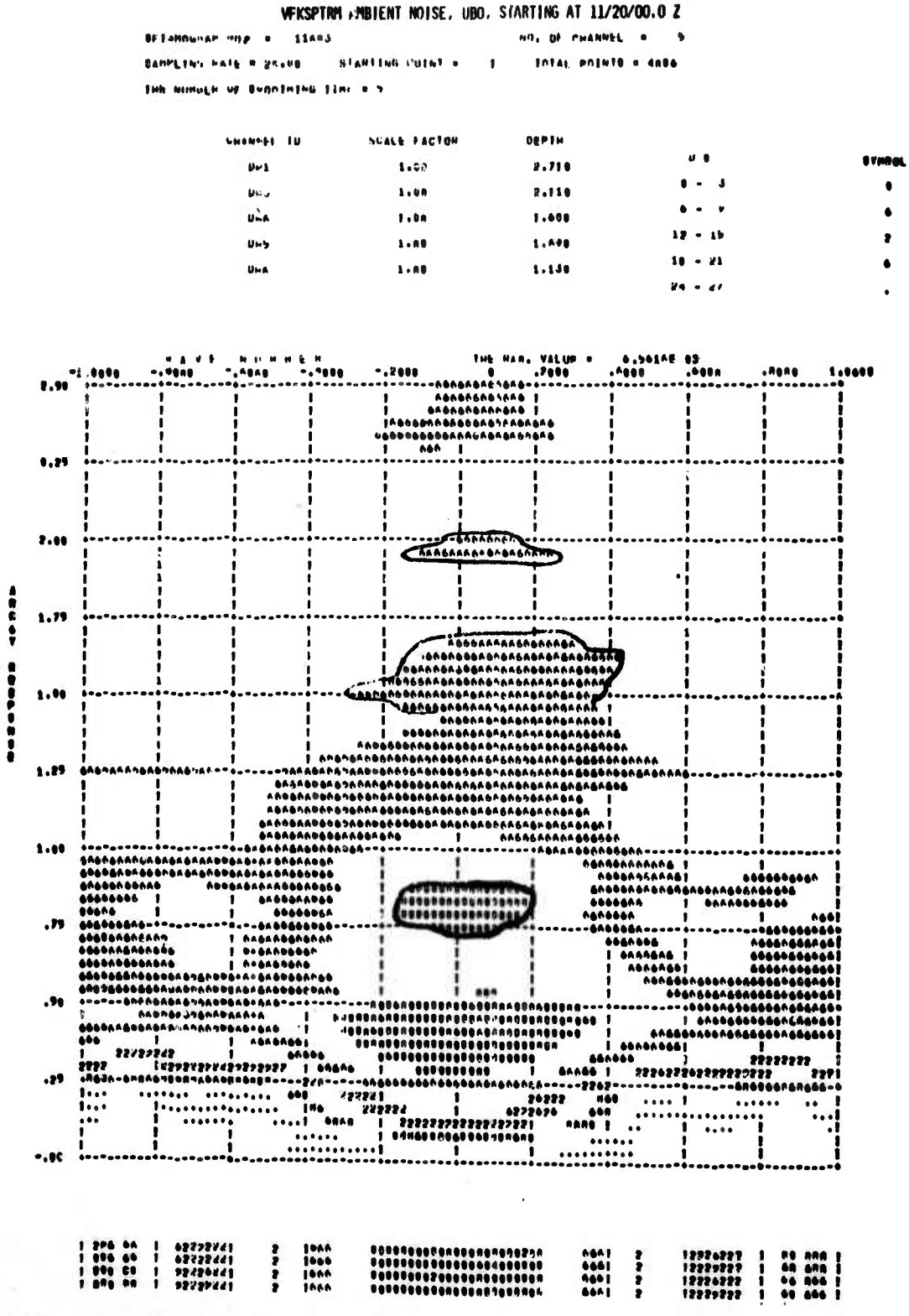

Figure 12. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

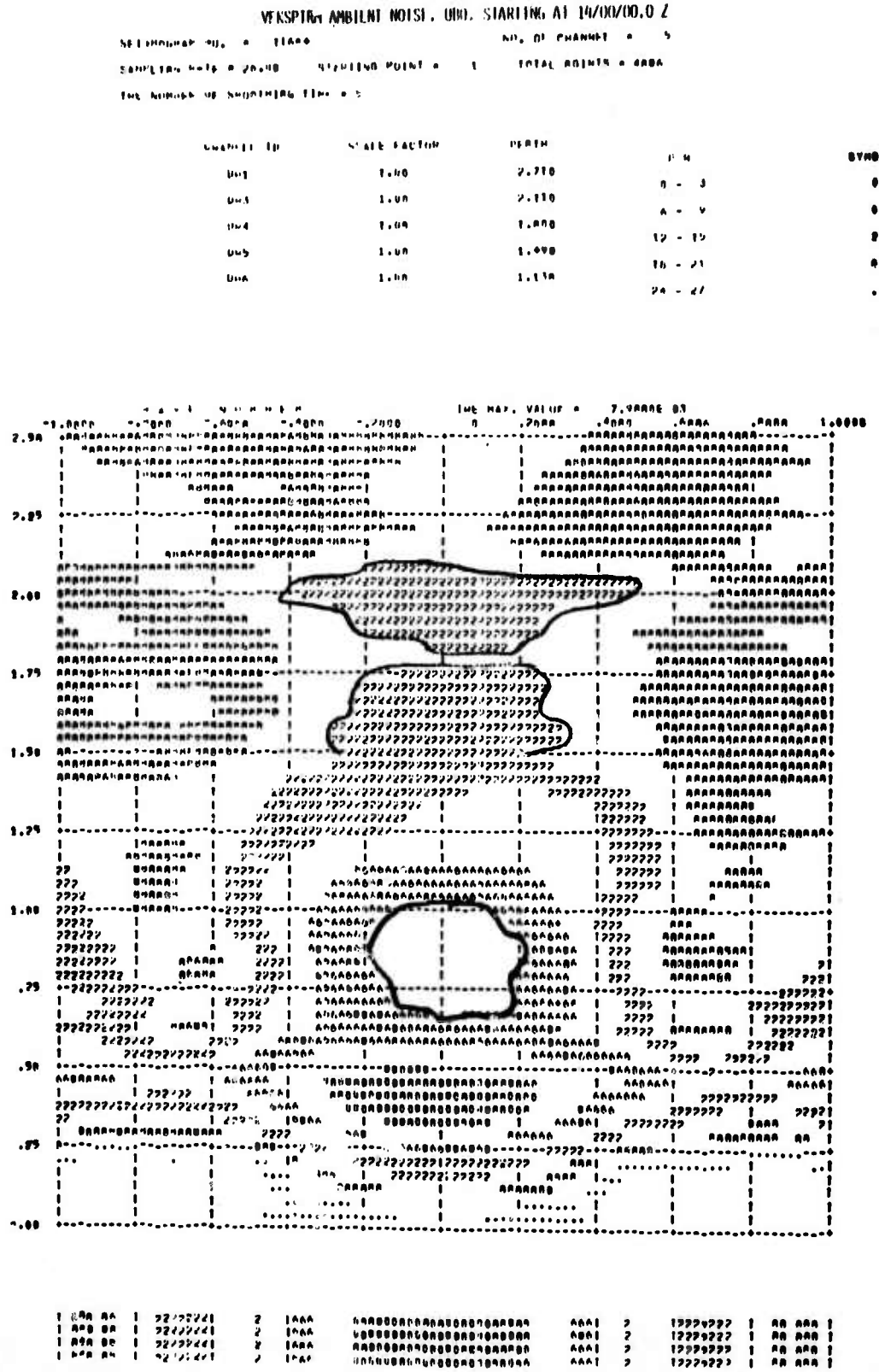

Figure 13. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

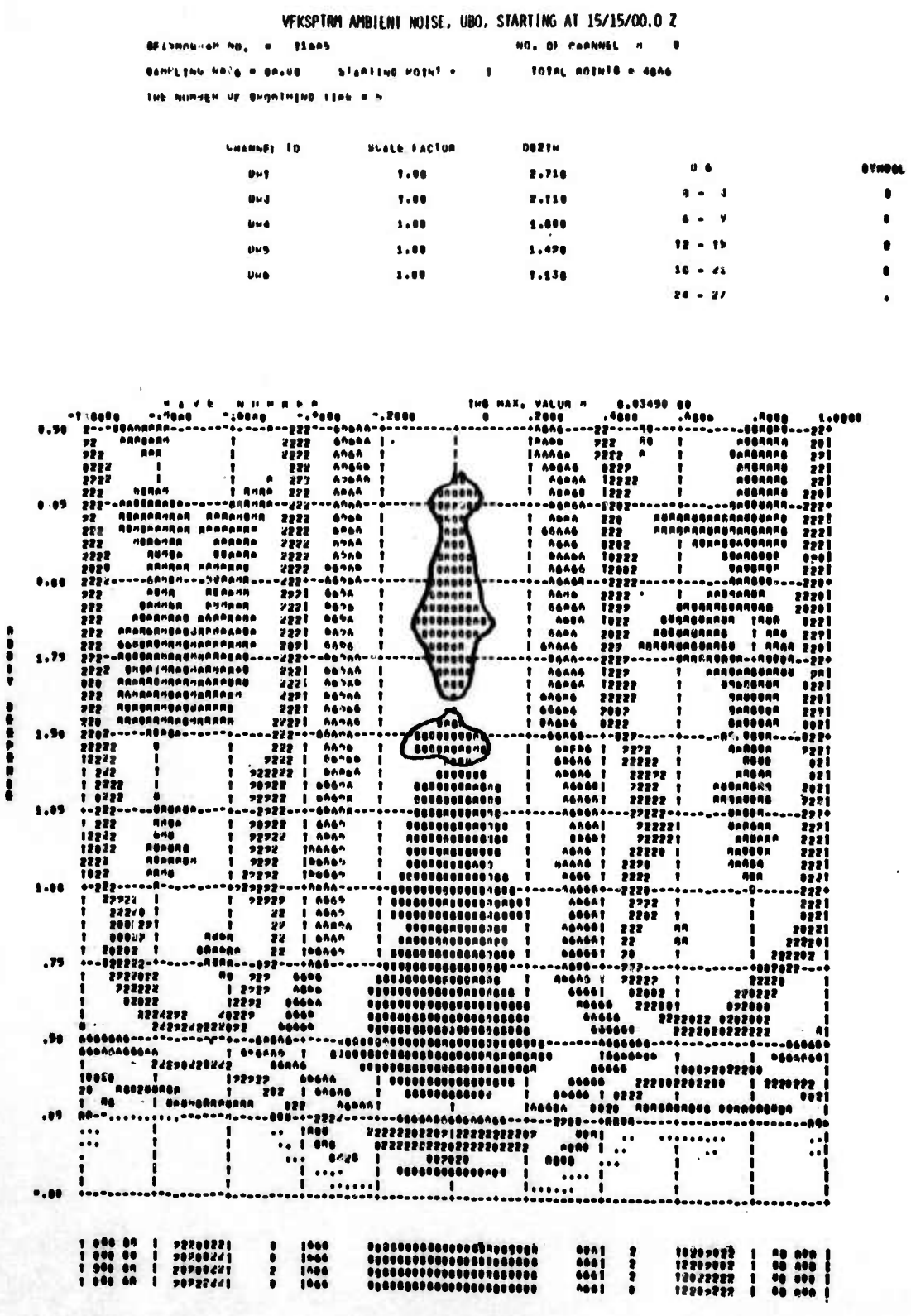

Figure 14. Filtered Noise Band: (.3<f<3cps)
Rolloff: .1cps

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